

TECHNOLOGY TRANSFER: MOVING R&D TO OPERATIONS

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Introduction

The Federal Aviation Administration (FAA) under the new Air Traffic Organization (ATO) has adopted performance-based management of air traffic control system delivery of new technologies. FAA modernization projects are to “focus more on accountability and tracking costs related to service goals: and not change the technologies themselves.”¹ To accomplish this, senior management, before committing resources to move a product into operations, requires a good sound business case to demonstrate how new products and services will improve efficiency and safety of the National Airspace System (NAS). Thus the best idea needs a path to implementation on an operational platform that can support goals in the Administrator’s Flight Plan 2004-2008.

The Aviation Weather Technology Transfer (AWTT) process, established in 1999, supports the concept of developing a business case to move weather R&D products into operations. The AWTT process falls under the auspices of Air Traffic Operations Planning and is led by a governing board. Since, its inception it has evolved significantly and will continue to change to meet the operational needs of the new ATO Organization.

The board is comprised of members that cut across FAA services and includes representation from NWS. The AWTT board encourages the development of new aviation weather products to improve the depiction and forecasting of weather events that affect not only the safety of the NAS but also the efficiency. This paper describes the functions of the board and the AWTT process.

Functions of the AWTT Board

In 1999 FAA’s Air Traffic Requirements Services agreed that there was a need to have program to provide oversight on the transfer of new aviation weather products into operations. Products were being developed in the R&D community did not have a well-defined path to implementation on an operational platform. Having senior FAA and NWS managers on the AWTT Board brings together

decision makers who can obligate the required resources to implement the product development onto operational platforms.

In addition, the senior leaders on the Board provide direction to developers of new products on the needs for service that do not require major material procurement or in other words non-material solutions. For example, it has been recognized and widely accepted that weather is a major contributor to delays and accidents in the National Airspace System (NAS). Many of the solutions to mitigate weather impacts on operations are geared towards non-material solutions. But for the most part many of the proposed changes in providing timely information on hazardous weather are software development issues using existing technology or platforms to display or provide a new or different product so decision makers have more timely and factual information on the hazardous weather.

R&D to Operations—the AWTT Process

Organizationally, the AWTT process is a four part series with four key decisions points, each requiring different input and supporting documentation. In some circumstances the information requested for the Board is a refinement or expansion of existing documentation to further embrace the development of the product. Figure 1 shows the conceptual process of the AWTT process. Under the auspices of the Board there is AWTT Steering Group (ASG) who serves as staff to the board. The ASG advises the Board members on the progress of the various programs that require the Board’s oversight. One key element that needs to be understood is that the AWTT oversees programs being supported by FAA’s R&D or Facility and Equipment (F&E) funds. The Board does not have authority to obligate funds. However, members to the Board who have operational platforms under their responsibility can thus plan accordingly to budget resources based on an agreed implementation plan.

D1 Stage

The AWTT Board only becomes engaged in decision making for those actions that require a D3 or D4 approval. For D1 and D2 actions the ASG has oversight and responsibility to ensure that the work being performed under R&D is in support of FAA

¹ “Setting up the ATO”, Development and Training News, FAA, Dec 5, 2003, www.ato.faa.gov.

mission and requirements to develop operational aviation weather products. Decisions approved at the D1 and D2 stage are approved jointly by first line managers in the respective Air Traffic Operations Planning, National Weather Service, and Flight Standards offices who serve on the ASG. Note that a D1 decision requires developers to have a sponsor to support the work they are performing. As part of that process a developer should be responding to a user needs assessment or analysis that provides direction on what is being requested in services but does not drive the solution. To further support a D1 decision an initial Concept of Use (ConUse) document should be prepared to describe conceptually how the product would be used in operations or meet a stated goal or requirements. By necessity, this initial ConUse will be general and flexible enough to accommodate changes in direction of the research as opportunities arise.

D2 Stage

A D2 decision by the ASG allows the developer to move from a concept to a product that needs to be tested in a lab or simulated environment. The product may remain in the D2 stage for several years until the developer believes that the product is ready for advancement. The ASG does not have direct input during this process but should be kept informed of the work that is under progress and be consulted on a periodic basis to help support the continuation of this work during situations that may require budgetary support.

D3 Stage

When entering a D3 decision, the Board is requested to convene and make a determination that the proposed product is ready for experimental testing. This is a critical stage in that the FAA is sanctioning the potential use of the product. Crucial to obtaining Board approval is the preparation of a detailed ConUse plan. Table 1 provides an outline of what is to be included in a ConUse plan. Even though the product is still in an experimental stage the developer, in consultation with the users, should have a clear consensus and understanding of how the product is to be used in operations for the purpose of the testing. This understanding then leads to the need to develop a detailed test plan that will demonstrate how the product can be accessed, used, and verified. Included in the test plan is the need to develop a metric or standard to measure against the success of the product. Quite often the minimum for success is that the product does no worse than existing capabilities; however, under today's austere budgets

developers need to set higher standards of success if the Board is to agree that a product is beneficial to users of the NAS. Another requirement is an initial scientific/technical review. A favorable conclusion on the scientific merits of the project helps show that the product shows promise, though it may need further refinement. The goal in this evaluation process is to facilitate the weeding out of any proposed products that may not be based on sound scientific principles or that appear to have no potential for future maturation.

Also, this D3 stage is critical because it begins the process for requesting an Operational and Maintenance (O&M) budget with the anticipation that the product will be operational on a FAA platform for a defined out year. It also further defines whether there is need to enter the FAA Acquisition Management System (AMS) process that requires the development of a mission needs analysis and other supporting documents. Most important and critical at this stage is obtaining concurrence from FAA's Flight Standards Service before being released to a controlled test group where it can be displayed on a sanctioned FAA test bed such as the NWS Aviation Weather Center Aviation Digital Data Server (ADDS). As part of this approval process the developers are required to prepare and present a test plan that describes the objectives of the project, how the testing will be conducted and how the test supports the ConUse. In addition, an initial Implementation Plan (IP) is written to detail tasks each responsible organization must accomplish to ensure smooth transition through the experimental applications stage into operational implementation. The IP includes, among other issues, actions on system architecture, product integration, training, and labor-management relations.

D4 Stage

Once a product has completed its experimental testing it can be considered ready for a D4 decision. In this stage, a final ConUse is written to describe how the product will be used in an operational environment. Included in this ConUse is direction to change other supporting documents on the use of the product such as the Airmen Information Manual (AIM), and further refinement of risks and benefits. In addition, the product has undergone more intensive scientific/technical review and has been judged as technically valid and scientifically sound. The sole basis for the technical review panel conclusion is the scientific and technical validity of the product. The technical review panel does not consider operational utility and human factors

qualities, which are evaluated separately with the end users.

Also, if all goes as planned there should be an O&M budget in place to transition the product into an operational environment. To ensure that the product can be advanced to operational a D4 decision requires an implementation plan. The plan identifies the responsibilities of various services to ensure that the product can be operational on the agreed too implementation date. Critical to the implementation plan is the identification of users and platforms that product is to be made available to. Funding is more forth coming from the FAA to further advance this project as in this stage a more refined con use emerges and risks have been identified with the possibility of success.

Public involvement

The proceeding sections described the boxes that had to be checked to move through each stage to the end state. Critical to meeting the requirements for Stages 3 and 4 is public involvement. The FAA has learned that public user input is key to the success to the deployment of any new product. Without customer acceptance of the new product it will never succeed. Not to be forgotten are the FAA's bargaining units. Their input is solicited and critical to any successful deployment of a new product. Implementation of any new product on an operational platform requires procedures and training.

Obtaining customer input and addressing bargaining units concerns can be a formidable challenge at times. As a means to gather public input the FAA conducts quarterly public meetings to solicit input from the public by reviewing the status of various

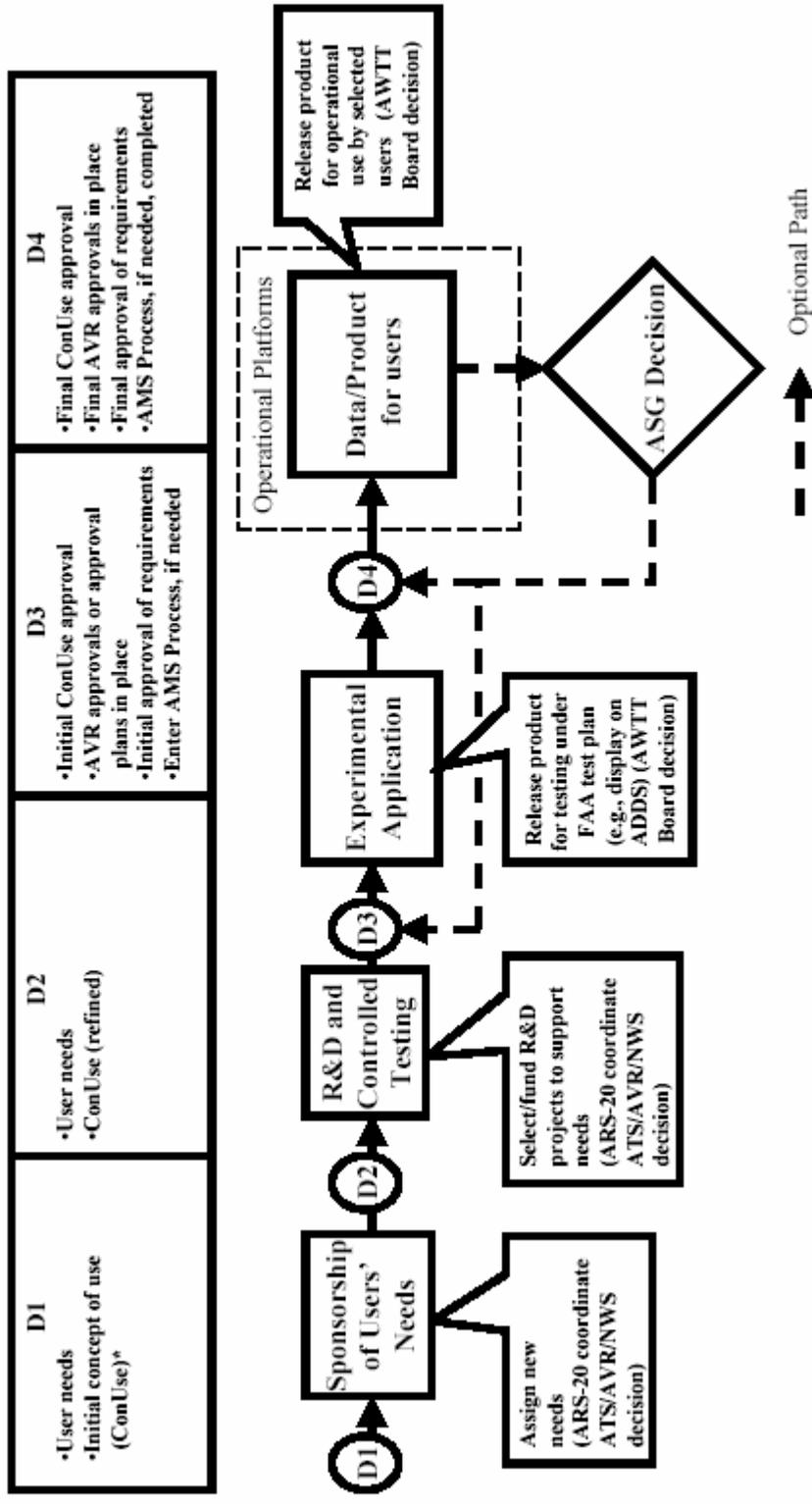
programs, discussing a roadmap to implementation and allowing users to interact with the developers. During the public discussion the FAA describes the attributes of the product and describes how it will be used in the NAS. It should not be assumed that a product will be given *carte blanche* approval for use by all users of the NAS. Experience has shown that many of the new products and innovations are not ready for stand-alone operation to replace existing hazardous messages. On the other hand these new products are used to supplement existing capabilities or can be used as guidance for input to the official hazardous message. The eventual end stage is to develop products that have greater capability to provide timely and more accurate information than existing messages, but the FAA deems it useful to phase in products when it believes there is value added to the services. Bargaining units issues are addressed separately but at the end all significant issues have to be addressed and resolved for both the public and the bargaining units.

Conclusion

The FAA has established a process that helps to accelerate the transfer of technology into operations. At the present time the FAA is further refining its management and oversight of this approach. New products bring new challenges that must be resolved before they can be approved in an experimental and operational mode. The FAA needs to ensure that the information being provided is not misleading and that those users who may be participating in an experimental phase or plan on using the product to support operational decisions fully understand the attributes of the product and information being provided.

**Table 1 Guidelines for Con Use Plans to support
Experimental or Operational Decisions for the
AWTT Board**

1. Introduction
 - 1.1. Purpose
 - 1.2. Drivers
2. Description of the Need
3. Description of the Product
 - 3.1. Technical Description
 - 3.2. How New Product/Capability Address Shortfalls
 - 3.3. Product Output
 - 3.4. Regulatory Impact
 - 3.5. Relationship to Other Domestic or International Products
4. Product Usage
 - 4.1. Impact of New Product/Capability on Operations
 - 4.2. Accessibility
 - 4.3. Limitations
 - 4.4. Training
5. Evolution of the Product
 - 5.1. Replacement and Changes
6. Performance, Benefits and Costs
 - 6.1. Performance Metrics
 - 6.1.1. Description of how to measure "goodness" of the product
 - 6.1.2. Criteria for success
 - 6.1.3. Technical performance standards
 - 6.2. Description of the Benefits
 - 6.2.1. Benefits of Using the Product
 - 6.2.2. Impact of Not Implementing the Product
 - 6.3. Description of the Costs
 - 6.3.1. Budget Impacts
 - 6.3.2. Other Costs
 - 6.3.3. Who pays?



- These product improvements are not currently under the AWTT process

Figure 1. Aviation Weather Technology Transfer (AWTT) process, showing major milestones and key tasks associated with each milestone.

EFFECTS OF VOLCANIC ACTIVITY ON AIRPORTS

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Introduction

In addition to posing a hazard to in-flight aircraft from airborne volcanic ash, volcanic activity also can disrupt operations at airports, with both local and global consequences for modern life and commerce. Worldwide, approximately 500 airports lie within 100 km of volcanoes that have erupted since 1900 AD. The primary volcanic hazard to airports is ashfall, which causes loss of visibility, structural damage, contamination of ground systems and parked aircraft, and slippery runways. Temporary airport closures have resulted from accumulation of just a few millimeters of ash. On rare occasions, airports also have been damaged by pyroclastic flows (e.g., on the island of Montserrat, British West Indies, in 1997) and lava flows (notably, at Goma, Dem. Rep. of Congo, in 2002). Ash in airspace around airports has damaged in-flight aircraft (e.g., near Guatemala City, Guatemala, in 1999), and airport closures may involve loss of alternate landing sites required for operation of long-distance twin-engine flights (particularly for flights over the North Atlantic).

Ash-contaminated airports can operate with due caution. Practical operational guidelines, based on experience at numerous airports, have been published by ICAO (International Civil Aviation Organization, 2001) and the U.S. Geological Survey (Casadevall, 1993). At-risk airports should have such information on hand as a basic preparedness measure and consider developing operational plans for ashfall events.

Extent of the Volcanic Hazard to Airports

Airport and volcanic data collected by the U.S. Geological Survey's Volcano Hazards Program and the Smithsonian Institution's Global Volcanism Program illustrates the extent of the volcanic hazard to airports. Information about reported instances of airports affected by volcanic activity was gleaned

from various sources, including news outlets, volcanological reports (particularly the Smithsonian Bulletin of the Global Volcanism Network), and previous publications on the topic (e.g., Casadevall, 1993). For each instance, information about the airport (such as latitude, longitude, country) and a brief description of the operational disruption have been compiled along with data on the volcanic source (such as latitude, longitude, eruption date, volcanic explosivity index).

Analysis of the resulting database reveals that from 1944 through 2003, operations at airports in at least 75 cities, towns, and military bases in 20 countries (Table 1) were disrupted on 108 occasions by eruptions at 34 volcanoes. This is not a complete inventory of airport disruptions because incidents are not always reported; nevertheless, it is a good sample from diverse parts of the world. About 50% of the impacted airports are located within 100 km of the source volcano, but operations at airports as far away as 500 to 1700 km from the eruptive sources have been disrupted. Some airports have been affected repeatedly – *viz.*, at Anchorage in the USA, Bramble (now destroyed) on Montserrat, Catania in Italy, Guatemala City in Guatemala, Kagoshima City in Japan, Mexico City in Mexico, Quito in Ecuador, and San Juan in Puerto Rico.

The 34 source volcanoes are in 14 countries (Table 2). The volcanoes that most often disrupt airports are Mount Etna in Italy, Sakurajima in Japan, Popocatepetl in Mexico, and Soufriere Hills on the Island of Montserrat in the British West Indies. Soufriere Hills Volcano, although the source of relatively small ash clouds since 1995, has affected the most airports (11), which is not surprising given its proximity to many other islands with airports. Indonesia and the United States have the most volcanoes (5 each) reported to have caused airport disruptions.

An important factor in determining whether an eruption will affect a specific airport is the wind field at the time of eruption. For example, the

prevailing winds in the Pacific over the Mariana Islands blow predominantly but not exclusively toward the west, and during most of the May-July 2003 eruption of Anatahan Volcano ash was dispersed away from population centers lying south of the volcano. But on 23 May 2003, winds from Typhoon Chan-Hom pushed the ash plume southward, dusting Saipan and causing flight cancellations there and at Guam, 320 km south of the volcano.

Reducing Operational Disruptions

With some forewarning of imminent volcanic hazards and an operational plan for ash events in hand, a vulnerable airport can take measures to mitigate the disruptive effects of ashfall. Such measures include conducting cleanup quickly and efficiently, moving or covering parked aircraft, optimizing runway usage, and reducing closure time. Recommended clean-up procedures and other mitigation actions are summarized online at: <http://volcanoes.usgs.gov/ash/trans/index.html>

Methods of forewarning of volcanic activity that have been used by airports include: (1) real-time detection of explosive volcanic activity; (2) forecasts of ash-plume paths; and (3) detection of approaching ash plumes using ground-based Doppler RADAR.

Real-time detection of explosive volcanic activity at Sakura-jima Volcano, Japan, allows use of the nearby airport in Kagoshima City despite the volcano's frequent eruptions (>7,300 eruptive events since 1955). Eruptive phenomena are monitored around the clock and in all weather conditions with continuously transmitting seismic and infrasonic instruments designed to distinguish explosive, ash-producing eruptions from volcanic earthquakes and tremor without ash production. When the monitoring system detects an explosive eruption, a warning is automatically sent to flight dispatchers at Kagoshima International Airport. Dispatchers then check wind data and visibility and rapidly issue a recommendation to pilots (e.g., divert to another airport, maintain holding position, select alternate arrival route, or select normal arrival route). The monitoring/warning system used at Sakura-jima has proven very effective at reducing risks to aviation in an unfavorable volcanic environment (Onodera and Kamo, 1994).

Forecasts of ash-plume paths, based on ash-trajectory models for eruptions from proximal

volcanoes, provided valuable forewarning to airport operators and the airline industry during the 1989-1990 eruption of Redoubt Volcano in Alaska (Murray and others, 1994). The Alaska Volcano Observatory (AVO) and the Anchorage Weather Service Forecast Office adapted a NOAA model that predicted plume trajectories for 3-hr intervals based on forecast wind fields. Before an eruption, the model was used to estimate where and when ash would be blown. Twice daily, after the predicted wind fields were updated, AVO would plot the trajectories predicted for the next 72 hours. These trajectories were on hand when an eruptive event occurred and were distributed by fax to all interested parties who could then act accordingly to mitigate the effects of volcanic ash. For example, Anchorage airports could optimize the times that runways were kept open. In general for airport needs, ash-dispersion and trajectory models should have the capability to: indicate where ash would go in the first one to two hours after an eruption; estimate arrival time of ash at a particular location in addition to estimating ashfall thickness; and deal with small- to moderate-sized recurring eruptions with little ashfall as well as major ash-producing events.

Detection of approaching ash plumes using ground-based Doppler RADAR was applied in Mexico City, located about 60 km from Popocatepetl's summit and within the volcano's ash-hazard zone. In 1997, Mexico's National Center for the Prevention of Disasters (CENAPRED) and the U.S. Geological Survey used an experimental ground-based Doppler RADAR to track the direction and speed of ash plumes, especially when visual confirmation was difficult at night and in bad weather (Hoblitt and Quaas Weppen, 1999). When the combination of seismic and RADAR data confirmed an eruption had occurred, alerts were given to air-traffic controllers at Mexico City International Airport to prevent encounters of aircraft with ash around the airport. The experimental system used in Mexico eventually suffered a hardware failure, and development of a robust system is needed for further volcanic applications.

Conclusions

Given the demonstrated vulnerability of airports to disruption from volcanic activity, vulnerable airports should have basic preparedness information on hand, evaluate appropriate systems that can provide forewarning of imminent volcanic-

ash hazards, and develop operational plans for ashfall events. Such a plan describes: methods and available equipment for clean-up, procedures for incorporating up-to-date information from a volcanological agency about eruptive activity from the proximal volcano(es) into operational decisions, protocols for making the decision to close an airport to ensure aircraft and passenger safety, and procedures for managing air traffic in ash-contaminated airspace in the vicinity of the airspace.

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Table 1. List of cities, towns, and military bases in which airport operations were disrupted by volcanic activity, 1944 through 2003, organized by country.

Antigua

Saint John's

Argentina

Buenos Aires, Comodoro Rivadavia, Cordoba, Jujuy, Mar del Plata, Neuquen, Puerto Deseado, San Julian, Salta

Colombia

Pasto

Dem. Rep. of Congo

Goma

Dominica

Roseau

Ecuador

Ambato, Cuenca, Guayaquil, Quito, Riobamba

France

Unnamed airport(s) on Guadeloupe

Guatemala

Guatemala City

Indonesia

Bandung, Gorontalo, Manado, Medan, Surabaya, Unnamed airport west of Gamalama volcano

Italy

Catania, Reggio di Calabria, Naples, Sigonella Naval Air Station

Japan

Kagoshima, Mijake-jima

Mexico

Colima, Mexico City, Puebla, Unnamed airports in SE Mexico

Netherland Antilles

Sint Maarten

New Zealand

Auckland, Tauranga

Paraguay

Asuncion

Philippines

Basa Air Base, Clark Field, Cubi Point, Legaspi, Manila, Puerto Princesa, Sangley Pt. Air Base

Papua New Guinea

Kimbe, Kavieng, Port Moresby, Rabaul

St. Kitts

Unnamed airport

United Kingdom

Unnamed airport on Anguilla, Bramble (Montserrat), Stanley (Falkland Islands)

USA and Territories

Anchorage, Elemendorf Air Force Base, Grant County, Guam, Kenai, Merrill Field, Missoula, Portland area, Pullman, Roosevelt Roads Naval Air Station (Puerto Rico), Saipan (Mariana Islands), San Juan (Puerto Rico), St. Croix (US Virgin Islands), St. Thomas (US Virgin Islands), Spokane, Unnamed airports on south Texas coast, Yakima

Table 2. Volcanoes whose eruptions are known to have caused operational disruptions at airports, 1944 through 2003, organized by country.

Chile

Hudson, Llaima, Lascar

Colombi

Galeras

Democratic Republic of the Congo

Nyiragongo

Ecuador

Guagua Pinchincha, Reventador, Tungurahua

Guatemala

Fuego, Pacaya

Indonesia

Agung, Galunggung, Gamalama, Lokon,
Soputan

Italy

Etna, Vesuvius

Japan

Miyake-jima, Sakura-jima

Mexico

El Chichon, Colima, Popocatepetl

New Zealand

Ruapehu, White Island

Papua New Guinea

Lamington, Pago, Rabaul

Philippines

Pinatubo

United Kingdom

Soufriere Hills (Montserrat)

USA and Territories

Augustine, Redoubt, Spurr, St. Helens,
Anatahan (Mariana Islands)

AN AIR TRAFFIC CONTROL PERSPECTIVE ON VOLCANIC ASH: HOW TO DEAL WITH IT

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The majority of the air traffic controllers in the National Airspace System have limited or no experience in controlling traffic when there is volcanic ash. Although controllers who work specifically at San Juan have little knowledge of the affects of volcanic ash, they have to deal with this hazard on a routine basis.

This paper will discuss the weather issues associated with ash from the Soufriere Hills volcano located on the island of Montserrat and provide a historical overview of how it affects aviation airways in the San Juan airspace.

The two most important factors in determining volcanic ash are forecasting and observations. Within the Federal Aviation Administration, three specific organizations collect volcanic ash information, the towers, the centers, and the flight service stations. Pilot reports are the name given to the collected weather observations by airborne aircraft. The function of the flight service station is to receive pilot reports and disseminate the information to its users. The goal of the flight service station is to keep everyone informed expeditiously. The aviation industry and the flight service station are the other eyes and ears of the National Weather Service. After pilot reports are processed, they are issued to the National Weather Service and other concerned agencies. Whereas the purpose of forecasting is to predict, the purpose of observations is to verify. Whenever mid-level clouds block satellite imagery, the use of pilot report enhances forecasting. There are occasions when pilot reports do not conform to the forecasted models. Weather information received from the flight service station is trustworthy for all types of pilot reports.

Puerto Rico the smallest of the Greater Antilles is located 350 nautical miles northwest of the island of Montserrat. This geographical position places it in the direct path of volcanic ash. In addition, St. Croix, the southern most of the U. S. Virgin Islands and the Puerto Rico

municipal islands of Vieques and Culebra located on the east and southeast coast of Puerto Rico are also in the direct path of volcanic ash.

WEATHER ISSUES ASSOCIATED WITH VOLCANIC ASH

The determining factors for the movement of volcanic ash are the atmospheric conditions that surround it.

Historically, volcanic ash creates an aviation hazard at both the lower and upper altitudes. Surface high pressure over the Atlantic will generate a southeast wind component that can lift volcanic ash to about 10,000 feet and move it in a northwesterly trajectory. The normal trade wind flow will usually keep volcanic ash within the airspace of the Lesser Antilles. However, any changes to the position of the high pressure will change the prevailing direction of the wind. When the pressure gradient generates moderate to strong southeasterly winds, it can act as the medium for pushing volcanic ash into the San Juan airspace. Anytime the low-level winds are from the southeast, volcanic ash can carry into Puerto Rico.

As volcanic ash lifts into the upper atmosphere, other factors influence its movement. Sub tropical jet stream currents, upper level westerly winds and upper level troughs with an axis over Puerto Rico and a southwest flow aloft; can induce volcanic ash into the Atlantic and away from aviation airways. The result is that weather systems in the Caribbean and their movement greatly influence aviation in the San Juan and the Lesser Antilles airspace.

From Puerto Rico, the principal airways into the Caribbean are to the southeast and into the path of volcanic ash. Consequently, all facets of the air traffic system are equally impacted. The affects of volcanic ash on aviation in the San Juan airspace –

FROM THE VIEWPOINT OF THE AIR TRAFFIC CONTROL CENTER

1. Availability of altitudes – because of the different types of aircraft characteristics, not all aircraft can fly above the tops of volcanic ash.
2. Availability of airspace – volcanic ash affects navigational routes causing aircraft to fly around airspace with hazardous weather.
3. Lack of pilot reports – pilots are not sharing information in a timely manner so that other aircraft entering the affected airspace can plan accordingly.
4. Wastes of fuel – The routing of aircraft away from hazardous weather, will always incur the cost of extra fuel consumption. This, in turn, can lead to prioritizing aircraft out of sequence for arrival due to their fuel being below minimums.
5. Increase controller workload – aircraft that are in volcanic ash increase the workload at the adjacent control sectors. Controllers have to transition aircraft safely away from adverse weather.
6. Arrivals and departures delays – arrivals and departures become late in order to compensate for aircraft saturation in the different control sectors.

FROM THE VIEWPOINT OF THE FLIGHT SERVICE STATION

1. Pilot weather briefings increase – whenever there is an aviation weather hazard, all aviation interest including the ports authority request the latest and most current information.
2. Keeping the air traffic center updated – updates on weather advisories and pilot reports need to be timely and current.
3. Weather advisories – the receipt of significant weather advisories from the adjacent meteorological providers are either late or non-existent.

FROM THE VIEWPOINT OF THE AIR TRAFFIC CONTROL TOWER

1. Lack of knowledge - The lack of training and familiarization by general aviation limits their capacity to manage effectively the affects of volcanic ash on engine intake. The Federal Aviation Administration strongly recommends aircraft not to depart when there is the presence of volcanic ash
2. Engine intake - The possibility of engine intake from volcanic ash can greatly reduce aircraft mobility at the airport.
3. Pilot reports – The system users need to be more responsible and comply with request for pilot reports.
4. Aircraft scheduling - Airlines have the authority to determine aircraft scheduling. However, the lack of timely pilot reports and weather advisories makes it difficult to determine if the aviation hazard is either haze or volcanic ash.
5. Availability of gates – Scheduling also affects the availability of gates and create saturation by reducing the number of spaces open to parking.
6. Increase workload – When aviation hazards are lifted traffic on the ground increases. General aviation will tend to call the tower for volcanic ash information when they should be calling the flight service station for a proper weather briefing.
7. Reporting training disagreement – There have been instances where observers and the National Weather Service have reported volcanic ash or haze or a combination of both. Tower personnel have requested training to help them visibly identify and distinguish what is haze and what is volcanic ash.

FROM THE VIEWPOINT OF THE PORTS AUTHORITY

1. Breaking action of aircraft – Volcanic ash on the runway limits the breaking action of aircraft. In addition, the presence of precipitation mixed with volcanic ash creates a soapy substance and affects the runway drainage system. The outcome is that the runway has to be re-grooved.
2. Temperature variation – Because of the airport proximity to water there is a temperature variation between the surrounding land area, the runway, and the water. Wind direction can create a vortex that causes an uneven displacement of volcanic ash. Uneven accumulation of volcanic ash caused by a microburst can also affect the breaking action of aircraft.
3. Aircraft and airport equipment - Because volcanic ash is an abrasive, corrosion acts upon the movement of aircraft and airport equipment.
4. Reduced visibility - volcanic ash affects the airport lighting system reducing visibility.
5. The need for a letter of agreement - No joint letter of agreement exists between the National Weather Service, the flight service station, and the tower to keep the ports authority informed in a timely manner of aviation hazards.
6. Health hazard - in addition to an aviation hazard, volcanic ash is also a health hazard. Several employees at both the tower and the ports authority have complained that the presence of volcanic ash has caused bronchial asthma, sinusitis and respiratory ailments.

THE NEW ZEALAND VOLCANIC ASH ADVISORY SYSTEM

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1. INTRODUCTION

The Civil Aviation Authority of New Zealand (CAA) now recognise the New Zealand civil aviation industry's ability to manage its operations in proximity to volcanic ash with the aid of accepted civil aviation procedures and new information flow systems described in this paper. The Volcanic Ash Advisory System (NZVAAS) is primarily provided through the interactions of aircraft operators, Airways Corporation of New Zealand (ACNZ) and Meteorological Service of New Zealand (MetService). There is also important ground based volcanic information input from the Institute of Geological and Nuclear Sciences (IGNS).

The CAA no longer takes any part in the provision of operational volcanic ash information; however, it does continue to promote awareness of the NZVAAS and an understanding of the volcanic ash threat to civil aviation in New Zealand.

This paper is intended to illustrate the relationships between the NZVAAS participating agencies and show their various obligations in providing enhanced volcanic ash information to the civil aviation industry. In doing so it sets out supplementary procedures to the accepted ICAO practices, in particular the International Airways Volcanic Watch (IAVW) and Volcanic Ash Advisory Centre (VAAC) obligations and responsibilities.

2. DEVELOPMENT BACKGROUND

The volcanic activity of Mt Ruapehu had a significant impact on civil aviation in New Zealand during 1995 and 1996. Many flights were cancelled and many more diverted or re-routed. These episodes were the first time volcanic ash has impacted on modern aviation in New Zealand. New Zealand has a number of active volcanoes on or near the mainland and a number of volcanoes within its IAVW area of obligation.

The CAA operated a special Volcanic Ash Watch Office throughout the 1995/6 periods of volcanic activity at Mt Ruapehu. The Office's prime task was to manage volcanic ash affected airspace, restricted and danger areas, through the issue of formal Notices to Aviation (NOTAM).

A CAA and airline industry fact-finding team went to North America in July/August 1996 where it sought

advice on ways of operating aircraft near volcanic ash with minimum disruption. It was widely accepted that there was an increasing risk to aviation worldwide from the ejection of volcanic ash into the atmosphere. As a result of the fact-finding team's report, the way that ash affected airspace was managed and the type and volume of information available on that airspace was reviewed. The main issues to safely allow civil aviation to continue in proximity to volcanic ash were; ownership of the advisory system, improving alerts, improved tracking and drift prediction, airline discretion, contingent airspace management, operational communications and on-going education.

Work has continued in New Zealand to address these issues including: awareness promotion articles and posters printed and distributed by the CAA; incorporation by airlines of procedures to routinely report volcanic and ash activity using the standard Volcanic Ash Report (VAR) forms and procedures; improved ground based monitoring of volcanoes and implementation of alert paging systems linked to seismic monitoring equipment by IGNS; MetService has reviewed and strengthened its production of volcanic ash warnings (SIGMET) and its use of ash trajectory and dispersion models and ACNZ has set up a system to manage alternative routes affected by volcanic ash and implemented a CAA defined set of standard, ready to use, Volcanic Hazard Zone NOTAM.

Success in reducing the disruptive effects of ash on aviation is determined by information on the eruptions and the communication of relevant information to all interested parties. The NZVAAS primarily contemplates the three most risky volcanoes; Ruapehu, Ngauruhoe and White Island and takes into account other volcanoes in New Zealand.

3. THE MAIN VOLCANOES

New Zealand has a number of volcanoes, each with its own eruptive characteristics. Scientific study indicates that the majority must be considered as dormant, rather than extinct, and that they will produce eruptions at some indeterminate time in the future. New Zealand volcanoes can be classed as those that are frequently active or reawakening and those that are not. The cone volcanoes Ruapehu, White Island and Ngauruhoe are classified as frequently active and pose a real threat to aviation in New Zealand. Prior to any eruption, physical

precursors are expected to be identifiable; these may develop over time frames of days (and possibly only hours) for the basaltic sites, over months for andesitic sites, and over years for the rhyolitic sites. Such precursors provide the basis for the formulation and issue of warning information.

A volcanic eruption will produce a number of hazards, including ash that will have an effect on hundreds of kilometres of airspace. A volcanic event may build up over weeks to years and be relatively difficult to predict in its probable course and timing. However, ash ejected into the atmosphere can be tracked and its course predicted using conventional and developing meteorological methods. There is therefore a need for flexibility when undertaking volcanic planning. How these issues are managed can depend upon the known characteristics of each volcano, the amount of ash ejected and the prevailing conditions at the time of, or during, the event.

4. VOLCANO ALERT LEVEL

Ongoing volcano surveillance enables the background, or normal status, of a volcano or volcanic field to be determined. Variations of monitored parameters may indicate a change of status and the onset of an eruptive episode. An assigned 'Scientific Alert Level' defines the status of a volcano at any given time. Table 1 sets out the Scientific Alert Level criteria.

The New Zealand Volcano Scientific Alert Levels are based on a six-level system, with each level defining a change of status at the volcano or field. The lowest level (*dormancy*) is signified by '0' and the highest (large hazardous eruption) by '5'. The scale or size of an event will vary from volcano to volcano, ie; a Level '3' event at Ruapehu will be larger than a Level '3' at Ngauruhoe. Where information from the IGNS volcano surveillance programme indicates a change in a volcano's status (either up or down), IGNS will adjust the Scientific Alert Level by issuing a 'Science Alert Bulletin'

In the case of a volcano in the 're-awakening' category, a move from Level '0' to Level '1' does not necessarily signal imminent volcanic activity. Historically, seismic and deformation episodes have occurred at Taupo, Auckland, Rotorua, Okataina, and Raoul Island, which would have resulted in an adjustment to a level '1' alert with no accompanying eruption threat. Similar episodes leading to Level '1' alerts for volcanoes in the 're-awakening' category may be expected every 5 - 10 years.

Importantly, for the civil aviation community a change in the Scientific Alert Level triggers the immediate generation, or change of, a NOTAM on a Volcanic Hazard Zone (VHZ).

5. SYSTEM PARTICIPATION ROLES

Set out in Schematic 1 is a diagram showing the lines of communication and responsibility of participants in the NZVAAS.

5.2 Civil Aviation Authority of New Zealand

The CAA is responsible for ensuring a satisfactory means exists whereby civil aviation aircraft operations can be safely carried out near volcanic ash. The CAA is not responsible for providing any service to airlines to directly assist them with such operations. The CAA's role is to:

- (a) Review the effectiveness of the volcanic ash information system from time to time.
- (b) Ensure ACNZ, MetService and IGNS have any delegations or permissions required under the Civil Aviation Act 1990 to carry out their roles.
- (c) Publish, in the appropriate medium, a clear statement of how the volcanic ash information system works in New Zealand.
- (d) Continue to publish any appropriate educational or technical information on aircraft operation in or near volcanic ash, the volcanic situation in New Zealand or any other relevant material.
- (e) Establish any new Volcanic Hazard Zone (VHZ) that may be needed to cover volcanoes other than those currently contemplated.

5.3 Meteorological Service of New Zealand

MetService's responsibility is to provide civil aviation with enhanced and timely volcanic ash SIGMETs and any other volcanic activity or ash information packages required pursuant to New Zealand's ICAO obligations, and to maintain volcanic NOTAMs. MetService's role is to:

- (a) Maintain a watch over actual and possible volcanic events through the use of satellite and land based meteorological information systems and the use of atmospheric trajectory and dispersion models.

- (b) Notify IGNS of any possible eruption detected in New Zealand not already notified by IGNS.
- (c) Use suitable atmospheric trajectory and dispersion models to identify the probable path of ejected ash.
- (d) Use all appropriate internal and external procedures to generate timely SIGMETs to notify civil aviation of the present and likely future position of volcanic ash in New Zealand's area of responsibility.
- (e) Maintain a Volcanic SIGMET watch and update the SIGMET bulletin as frequently as possible and within the ICAO guidelines.
- (f) Provide any extra information such as satellite imagery, ash trajectory information or other graphics that may be requested by civil aircraft operators.
- (g) Provide information to IGNS such as wind profile data or independent observation information that may be appropriate.
- (h) When notified by IGNS of a change in the official activity level (Scientific Alert Levels) immediately request ACNZ to issue the appropriate NOTAM.
- (i) Maintain the currency of any related NOTAM in liaison with ACNZ.
- (j) Maintain a watch on technological developments and apply any advances in this area to operations.

5.4 Airways Corporation of New Zealand

The responsibility of ACNZ is to provide to civil aviation the NOTAM service, access to volcanic SIGMET and appropriate VAR information pursuant to New Zealand's ICAO obligations. It also collects, from aircraft, VAR information and disseminates this information to MetService, IGNS and accessible aircraft operators. The ACNZ role is to:

- (a) Ensure that meteorological reports (METARs, SPECIs) passed to MetService and civil aviation contains appropriate information on the presence (or not as the case may be during a volcanic episode) of volcanic ash or other volcanic phenomena.
- (b) Ensure that all AIREPs containing information on volcanic ash and Volcanic

Activity Reports (VARs) received from aircraft are passed with utmost urgency to MetService and any other addressees on the VAR distribution list.

- (c) Ensure that updated Volcanic SIGMETs provided by MetService are expeditiously passed to aircraft in flight, especially those operating in the vicinity of any ash.
- (d) Upon the receipt of a notification from MetService that the Scientific Alert Level of a given volcano has been changed, immediately issue the appropriate NOTAM. (Table 2 defines the vertical and horizontal limits of the VHZ for given scientific alert levels)
- (e) Notify MetService 24 hours before the expiry of any given NOTAM and request an update or confirmation of cancellation.
- (f) Set up a system to notify operators which routes and procedures will be affected by each level of volcanic activity.
- (g) Ensure that VFR or IFR aircraft that require an ATC clearance to operate within the areas of concern will not be granted a clearance without a specific route request from the pilot.

5.5 Institute of Geological and Nuclear Sciences

The prime responsibility of IGNS is to keep MetService informed as to any volcanic activity taking place in New Zealand. The role of IGNS is:

- (a) Maintain monitoring of volcanoes in New Zealand territory, particularly Ruapehu, Ngauruhoe and White Island, on a 24-hour basis. This should encompass the ability to confirm or deny any reported or suspected ash eruption.
- (b) Notify MetService of any change in assessed official activity level (ie; Scientific Alert Levels) immediately that decision has been made.
- (c) Notify MetService should the risk assessment of any volcano change positively or negatively (ie; Scientific Alert Bulletin).
- (d) Advise MetService of any new eruption information as it becomes available. This includes information on; eruption time and expected activity period, eruption type

(steam, gas, and ash) and any other relevant advice.

5.6 Aircraft Operators

The responsibility of aircraft operators is to ensure their aircraft do not operate in volcanic ash and to provide Volcanic Activity Reports (VARs) when appropriate. Their role is to:

- (a) Ensure procedures are incorporated in operations manuals for the reporting of volcanic events and ash, including the generation and distribution of these reports (VARs) following the prescribed international guidelines (ICAO).
- (b) Ensure that aircrew are fully aware of their civil aviation regulatory obligations insofar as Volcanic Hazard Zones (NOTAM) are concerned.
- (c) Ensure that aircrew have adequate background knowledge of the atmospheric and airframe effects of volcanic events especially in the context of the New Zealand volcanic situation.
- (d) Ensure procedures are incorporated in operations manuals for the safe operation of aircraft near areas of volcanic ash.
- (e) Ensure ACNZ is aware of their particular ash episode re-route preferences.

6. EXPERIENCE

Since the implementation of the NZVAAS in 1999, mainland New Zealand has not experienced any significant eruption events, although the NZVAAS system has been operating on a number of occasions. To ensure the system will operate well when the inevitable more significant volcanic event does occur, MetService conducts annual exercises, internally producing simulated agency outputs, interaction and responses. These exercises have been very helpful in both maintaining the currency of staff involved and in streamlining and improving processes.

Experience with the issue of volcanic ash information in New Zealand has highlighted the difficulty on occasion of providing detailed information about volcanic ash in both textual and graphical formats. This can be a significant issue when eruptions from a particular

volcano are continuous or quasi-continuous over a period of time, and when wind direction varies with height causing ash to move in different directions with height. Depicting this information graphically has proven to be difficult, and describing the information in textual messages has often resulted in lengthy and very complex messages.

Over the time the NZVAAS has been operating, there has been increased interest in Government regarding overall geophysical risk mitigation. This has proved fortunate for the NZVAAS as it has resulted in better monitoring of New Zealand's mainland volcanoes, and to a lesser extent, the offshore volcanoes.

Foreign airline operators taking up operations to or within New Zealand have had difficulty in understanding the context of the NZVAAS in relation to State IAVW responsibilities. There have also been charging issues arising out of the separate contracting for the NZVAAS as opposed to the standard service contract for ICAO Annex 3 prescribed meteorological services to individual airlines. In every case these issues have been resolved through careful explanation of the two systems. Nevertheless, it would be advantageous to move toward a structure that identifies the NZVAAS as a State based operational part of the overall IAVW.

In the absence of volcanic activity there is a natural tendency for airline operators to place less emphasis on volcanic ash risk mitigation procedures and systems. This seems to be inversely related to the size of the airline operation – the bigger operations have risk management personnel ensuring that their companies do maintain systems and carry out recurrency training. This is not always so with smaller operations. To increase the profile of volcanic activity risk, the CAA, MetService and ACNZ continue to highlight the NZVAAS and its advantages to the New Zealand aviation community.

7. CONCLUSION

The NZVAAS has proven to be a very effective system for New Zealand and this can be attributed largely to the formal arrangements between the participating organisations. It has also highlighted the importance of having co-operative and collaborative relationships between the regulator, the meteorological service provider, the air traffic service provider, the aircraft operators and the local volcanological organisation.

Schematic 1, New Zealand Volcanic Ash Advisory System

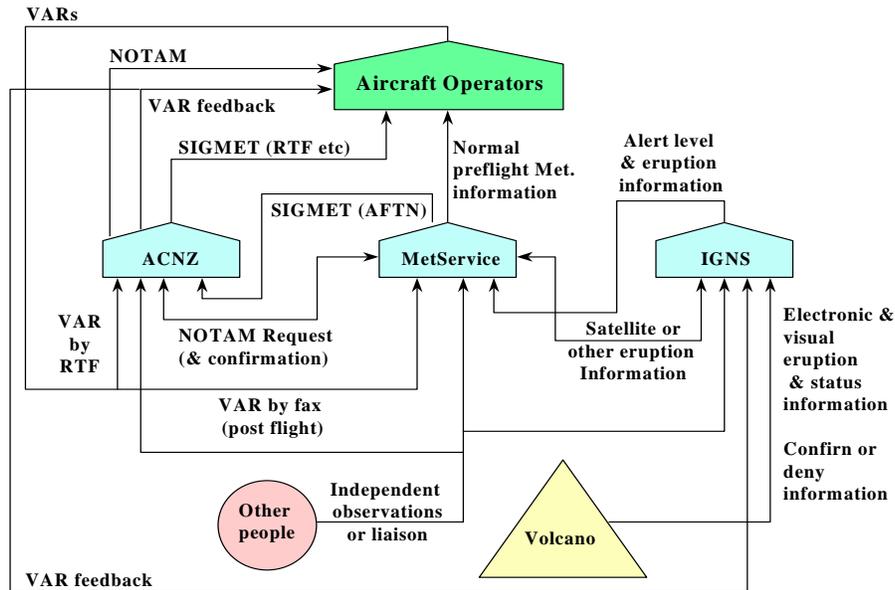


Table 1, New Zealand Volcanic Scientific Alert Level System

FREQUENTLY ACTIVE VOLCANOES White Island, Tongariro -Ngauruhoe, Ruapehu		SCIENTIFIC ALERT LEVEL	REAWAKENING VOLCANOES Kermadecs, Northland, Auckland, Mayor Island, Rotorua, Okataina, Taupo, Egmont	
<i>Volcano Status</i>	<i>Indicative Phenomena</i>		<i>Indicative Phenomena</i>	<i>Volcano Status</i>
Usual dormant or quiescent state.	Typical background surface activity; seismicity, deformation and heat flow at low levels.	0	Typical background surface activity; seismicity, deformation and heat flow at low levels.	Usual dormant or quiescent state.
Signs of volcano unrest.	Departure from typical background surface activity.	1	Apparent seismic, geodetic, thermal or other unrest indicators	Initial signs of possible volcano unrest. No eruption threat.
Minor eruptive activity.	Onset of eruptive activity, accompanied by changes to monitored indicators.	2	Increase in number or intensity of unrest indicators (seismicity, deformation, heat flow etc.).	Confirmation of volcano unrest. Eruption threat.
Significant local eruption in progress.	Increased vigour of ongoing activity and monitored indicators.	3	Minor eruptions. High increasing trends of unrest indicators, significant effects on volcano and possibly beyond.	Minor eruptions commenced. Real possibility of hazardous eruptions.
Hazardous local eruption in progress.	Significant change to ongoing activity and monitoring indicators. Effects beyond volcano.	4	Eruption of new magma. Sustained high levels of unrest indicators, significant effects beyond volcano.	Hazardous local eruption in progress. Large scale eruption now possible.
Large hazardous eruption in progress.	Destruction with major damage beyond volcano. Significant risk over wider areas.	5	Destruction with major damage beyond active volcano. Significant risk over wider areas.	Large hazardous volcanic eruption in progress.

Table 2, Automatic Volcanic Hazard Zone Limits for NOTAM

Volcano Alert Level	Radius from Vent (nm)	Volcanic Hazard Zone Upper Limit			
		Ruapehu (VHZ 314)	Ngauruhoe (VHZ313)	White Island (VHZ 211)	Any other NZ volcano
1	3	12,200ft AMSL	10,500ft AMSL	4,500ft AMSL	3000 ft above vent
2	8	FL 150	FL 150	FL 150	FL 150
3	16	FL 330	FL 330	FL 330	FL 330
4	27	FL 480	FL 480	FL 480	FL 480
5	>50	unlimited	unlimited	unlimited	Unlimited

PREVENTION OF VOLCANIC ASH ENCOUNTERS IN THE PROXIMITY AREA BETWEEN ACTIVE VOLCANOES AND HEAVY AIR TRAFFIC ROUTES

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1. Introduction

At the First International Symposium on Volcanic Ash and Aviation Safety in 1991, countermeasures against volcanic ash encounters were discussed and proposed by various scientific, aviation and government leaders. One of the most significant results that came out of this symposium was the establishment of the ICAO VAAC (International Civil Aviation Organization Volcanic Ash Advisory Center). However, recent reports indicate that the volcanic ash encounter from the Miyakejima volcano eruptions in 2000 could not have been prevented under the current ICAO system. This paper discusses issues on prevention of volcanic ash encounter in the proximity area between active volcanoes and heavy air traffic routes, by reviewing, as a case study, the Miyakejima volcano eruption case in Japan on Aug.18th, 2000, along with the incident from the Izu-Oshima volcano eruption in 1986.

2. Volcanic ash encountering incidents at the Miyakejima Volcano eruption on Aug. 18th, 2000

Miyakejima volcano is located approximately 110 nautical miles southwest of Narita airport in Japan. The explosive eruptions at Miyakejima volcano on Aug.18th, 2000 caused volcanic ash encounter by large transport aircraft in the vicinity of the volcano. Fig1 shows the location of Miyakejima volcano and the estimated points of volcanic ash encounters by two aircraft. In this region, there are many airways which have heavy air traffic volume in the proximity of the active

volcano. The question that arises from this Miyakejima incident in 2000 is why couldn't the volcanic ash encounters be prevented under the current ICAO regime, which was supported by various types of new technologies. In order to prevent further encounter incidents in this region it will be necessary to review the facts at the time of the volcanic ash encounter. The actions by the pilot and ATC (Air Traffic Control) controller are to be reviewed as well as information available at the time of encounter.

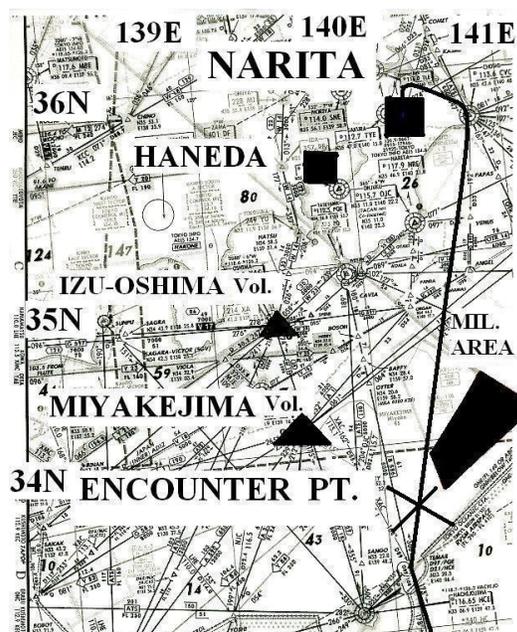


Fig.1. Area chart around volcanoes and encounter point on the avoidance route

2.1. Actions Taken By the Pilot

On Aug.18th, 2000, shortly after the explosive eruption had begun, volcanic ash encounters were reported by two Narita inbound flights, one was a B747 from Saipan, and the other was a B737 from Guam. Serious damage was found on both aircraft during a maintenance check at Narita. Both aircraft encountered volcanic ash while flying at FL340 and FL360 respectively on an air route to Narita near the Miyakejima volcano. The air space south of Narita is complicated by the structure of heavily flown air routes that are located in close proximity to an active volcano. In this air space, options for pilots and ATC controllers to alter a planned route during flight are very limited due to the threat of a possible mid air collision. In this area, arriving/departing routes to/from Narita and Haneda are closely located and/or crossing each other. In this region, it is especially important for pilots to fly strictly by following ATC instructions. Pilots, therefore, rely very heavily on the ATC controllers's decision making. The two aircraft which suffered a volcanic ash encounter were following ATC instructions at the time of the encounter, believing that ATC were radar vectoring them safely away from any volcanic ash encounter. But eventually the two aircraft inadvertently encountered volcanic ash. The pilot's ensuing actions were in accordance with the recommended procedures in the event of a volcanic ash encounter, which prevented an inflight engine shut down and led them to a safe landing at Narita. Even though an inflight engine flame out was prevented by the pilots' appropriate actions, the engines were seriously damaged, as well as other airplane components by the volcanic ash encounter. Questions still remain as to why both aircraft volcanic ash encounters could not be prevented while the

pilots were flying in accordance to ATC instructions.

2.2. Actions by ATC Controller

After Miyakejima volcano erupted, on Aug.18th, 2000, ATC controllers directed all Narita inbound flights from south to the furthest easterly route, believing that it was the safest course of action. However, the routes gradually became invaded with volcanic ash, and ATC could no longer provide effective radar vectoring (**Table1**). The information available at that time, which affected decision making in ATC, were SIGMET (Significant Meteorological information) and PIREP (Pilot Report). The volcanic ash transport and dispersion forecast were also provided to ATC. The ATC controllers were supposed to coordinate traffic flow and provide safe avoidance vectoring to concerned aircraft based on relevant information such as the volcanic ash forecast and/or SIGMETs, PIREPs and etc.,

Aircraft Type	Airport of Origin	Estimated ATO(z)	Narita Arrival(z)	Flight Condition
B747	SPN	0824	0859	Normal
B747	SYD	0831	0906	Normal
B747	GUM	0849	0924	Normal
B747	CNS	0905	0940	Normal
DC10	GUM	0916	0951	Normal
B747	SPN	0930	1003	Encounter
B737	GUM	0932	1005	Encounter

Note: Estimated ATO incident point are based on available data and calculation by the author

Table 1. Flight conditions of the encountered aircraft and the preceding aircraft on the same route

2.3. Information on the location and movement of volcanic ash, by the volcanic ash transport and dispersion forecast SIGMET, and PIREP

A various type of information had been issued at explosive eruptions at Miyakejima volcano on Aug.18th, 2000. The information was disseminated to relevant organizations according to the pre-determined destination table. Critical information, which would have affected the decision making on volcanic ash avoidance route by ATC, was thought to be included within the distributed information such as SIGMETs, VAAs (Volcanic Ash Advisory), and PIREPs.

2.3.1. Volcanic ash transport and dispersion forecast

Since the eruptions began at Miyakejima volcano in June, 2000, the volcanic ash transport and dispersion forecast was published and distributed to relevant organizations. On Aug.18th, 2000, at the time of the explosive eruptions of Miyakejima volcano, the volcanic ash transport and dispersion forecast was issued. However, the forecasted direction of the volcanic ash movement was southward from the crater, while the observed wind direction was southeastward. This slight disagreement of movement direction, between the forecast and

the observed one, may have affected, to some extent, the decision making process by ATC on which route to select as the volcanic ash avoidance route for approaching aircraft to the area. It was also revealed that the volcanic ash transport and dispersion forecast included, more or less, a forecast error, which could have adversely affected the decision by ATC on selecting the correct volcanic ash avoidance route. This case shows us that in an area where the air route is densely located, we cannot depend too much on the forecast in the contaminated area.

2.3.2. SIGMET, VAA

An extract of SIGMETs and VAAs is shown in **Table2**. The record of SIGMET and VAA indicates that the explosive eruption at 0802z on Aug.18th, 2000, was notified by VAA issued at 0815z, which mentioned that the plume height was above FL190. Then SIGMET No1 was issued at 0825z, stating that volcanic ash top FL190 and intensifying. VAA No2 at 0835z reported that the ash top above FL400 extending southeast. SIGMET No2 at 0840z stated, quoting PIREP at 0829z, that the volcanic ash top above FL400 drifting to E-SE and intensifying. VAA No3 at 0925z delineated area of volcanic ash as of 0832z and added the forecast area of volcanic ash contamination through the next day. Based on the record of SIGMETs and VAAs, the

Type of Information	Time of Issue (z)	Outline of Content
VAA No1	0815	Erupted at 0802z, ash climbing to above FL190.....
SIGMET No1	0825	Obs at 0802z VA top FL190 Movement unknown, intensifying...
VAA No2	0835	VA above FL400, extended SE, by PIREP at 0829z.....
SIGMET No2	0840	VA above FL400, moving E-SE, intensifying ,by B747 at 0829z....
SIGMET No3	0855	VA above FL400 moving E-SE, intensifying at 0829z by B747...
VAA No3	0925	VA obs by Satellite at 0832z 34.1N 139.4E,.... Outlook at 12z.....
B747	0930	Encounter VA at FL340 at approx 50 nm SE of volcano.
B737	0932	Encounter VA at FL360 at approx 50 nm SE of volcano.

Table 2. Extract from SIGMET and VAA on the Miyakejima explosive eruption initiated at 0802UTC on Aug.18th, 2000

issuance of the initial warning, VAA, was 13 minutes after the initiation of the explosive eruption. The timing of issuance of SIGMETs and VAAs were rather swift and quick under the circumstances. Although the SIGMET mentioned the height of the volcanic ash and the movement direction of volcanic ash from an early stage, the moving speed and the contaminated area of volcanic ash were not included until a later SIGMET. The lack of the critical information was another factor unfavourable to volcanic ash avoidance.

3. Comparison to the Izu-Oshima case in 1986

Aircraft Type	B747	DC8	DC10	B747
Time of Encounter (Z)	approx. 0900	approx. 0900	approx. 0920	Unknown
Portion	NRT-HKG	TPE-NRT	NRT-BKK	BOM-NRT
Location	60nm S of NRT	40nm E of Vol.	60nm E of Vol.	Unknown
Flight Phase	Climb	Descent	Climb	Descent
Altitude (feet)	20,000-30,000	30,000-26,000	20,000-23,000	17,000-10,000
Condition (Visibility)	Night(good)	Night(good)	Nighr(good)	Unknown
Observed Phenomena	Spark. Smell of burning wood	Unusual odour	Static discharge on windshield	Light to Mod turbulence
Aircraft Damage	None	Small particle like fog	Erosion (1). VA in pitot tube	Fine scratches on windshield

(1) Erosion was found on windsheild , horizontal and verical stabilizer.

Table 3. VA Encounter at Izu-Oshima volcano eruption on Nov.21st 1986

3.1. Izu-Oshima volcano eruption on Nov. 21st, 1986.

Izu-Oshima volcano is located approximately 80nm southwest of Narita airport and 38nm north northwest of Miyakejima volcano. On Nov. 21st, 1986, Izu-Oshima volcano erupted explosively and a volcanic ash cloud top soon reached a height of more than 10km above the crater. After this eruption, a volcanic ash encounter took place as shown in Table3. In this eruption, the volcanic ash encounter was approximately 40 to 60 nm east of the volcano, while at the Miyakejima volcano eruption in 2000, the encounter took place approximately

50 nm southeast of volcano. The relative distance between the crater and the encountering point in Miyakejima case is similar to that in the Izu-Oshima case.

3.2. Countermeasures against volcanic ash encounter

Table4 shows the countermeasures against volcanic ash encounters in 1986 and in 2000. It is clear that in 2000, we had much more data available than what we had in 1986. It can be said that, in 2000 we had better quantity and quality of data at hand than in 1986. In spite of much better conditions, the fact is that the volcanic ash incidents could not be prevented.

Year/Volcano	1986	2000
Countermeasures	Izu-Oshima	Miyakejima
Eruption Detection	Available	Available
SIGMET	Available	Available
NOTAM	Available	Available
Satellite Imagery	Available	Available
Split Window	N/A	Available
VAAC. VAA	N/A	Available
Dispersion Forecast	N/A	Available

Table 4. Improvement of countermeasures

3.3. Lead Time before encounter

Table5 shows the time sequence after the start of the explosive eruption until the actual volcanic ash encounter. The lead time

of the explosive eruptions before the encounter is approximately 1 hour 40 minutes in the Izu-Oshima case and 1 hour 28 minutes in the Miyakejima case. This fact shows that we had plenty of lead time before the actual encounter. We may have had more desirable results if we could have better utilized the lead time by continually updating and assessing the situation.

c. In the area where the air route structure is complex with a heavy load of air traffic in the proximity area to an active volcano, positive ATC decision making is crucially important for preventing volcanic ash encounters.

d. In those areas like c. above, basic education on the knowledge of volcanic ash encounter incident and practical education on the knowledge of volcanic ash avoidance is critical.

Time	Nov.21 1986 Izu-Oshima	Aug.18 2000 Miyakejima	Dec.15 1989 Redoubt
Eruption time	0720z	0802z	1915z
Encounter time	0900z	0930z	2045z
Lead time before encounter	1hour 40 min	1 hour 28 min	1 hour 30 min

Annual drills for ATC are essential in the area where heavy air traffic route are located in the proximity to active volcanoes.

Table 5. Lead time before volcanic ash encounter

4. Lessons learned from the incidents and the proposals for the area

These volcanic ash encounter cases are similar in the region of proximity of active volcano and heavy air traffic route. The Izu-Oshima volcano case in 1986 and Miyakejima volcano case in 2000 seems to indicate the following facts.

a. Volcanic ash encounters took place even after 14 years of progress in the international volcanic ash prevention program and the volcanic ash detection and movement prediction technique.

b. Even though pilot reports were submitted from an early stage after the eruption and SIGMETs were also issued consecutively, the volcanic ash avoidance route provided to Narita inbound flights from the southern airspace were not changed until after the encounter had taken place. This infers the difficulties of dealing with the information derived from SIGMET and PIREP, and the difficulty of applying them into the ATC decision making process for volcanic ash avoidance

Acknowledgement

I would like to thank those persons who provided me data pertinent to volcanic ash encounter incident in this region. At the same time I would like to thank those people who contribute to the prevention of volcanic ash encounter. I would like to specially thank the ex-director of SVO (Sakurajima Volcano Observatory, Kyoto University) and professor emeritus of Kyoto University, Dr.Kosuke Kamo, and the director of SVO, Dr.Kazuhiro Ishihara and SVO staff, and Dr. Hiroshi Tanaka, Tsukuba University, and Mr.Michael Kelly, Japan Airlines, for their continuous advise and help to the author since 1980s.

Reference

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A PROGRAM FOR RESEARCH AND SYSTEMS INTEGRATION TO HELP MITIGATE THE VOLCANIC ASH HAZARD TO AVIATION

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Introduction

The National Center for Atmospheric Research (NCAR) Research Applications Program (RAP) is currently addressing five aviation weather hazard areas through emerging weather products: convection and convective hazards; in-flight icing; turbulence (terrain-induced, convective-induced, jet stream, and shear); remote and oceanic weather hazard diagnosis and forecasts; ceiling and visibility. The National Weather Service (NWS) and Federal Aviation Administration (FAA) are transitioning these products to operations for use by pilots, dispatchers, flight service specialists, and air traffic controllers and managers. Underlying research, verification, dissemination methods, and user interface/display development have been sponsored primarily by the FAA Aviation Weather Research Program (AWRP), with joint sponsorship from the NASA Aviation Safety Program (AvSP).

The Oceanic Weather Product Development Team (OWPDT), one of eleven PDTs sponsored by the AWRP, is developing and introducing remote and oceanic weather products. The OWPDT, as one of its taskings in response to formal FAA requirements, is developing advanced techniques that will detect, forecast, and disseminate information on volcanic ash plume hazards to aviation operators and users. Airborne volcanic ash constitutes a recognized threat to aviation that can severely damage jet aircraft engines through erosion, corrosion and congestion. A number of well-documented near-fatal accidents have occurred, and even relatively minor encounters have resulted in extensive aircraft damage. Volcanic ash contamination may render large volumes of airspace unavailable, necessitating costly rerouting contingencies, and problematic ash-related aircraft encounters have been reported days after an eruption and thousands of miles from the source.

Current Volcanic Ash Products Available to Users

Current volcanic ash products available to aviation users include (as extracted from the FAA User Needs Analysis [UNA] document, dated 5 September 2001):

Volcanic Ash Significant Meteorological Information (SIGMET): The product generally describes the horizontal and vertical extent and the expected trajectory of the volcanic ash cloud.

Aviation Routine Weather Report/Special Aviation Weather Report (METAR/SPECI): An aviation weather observation for a specific airport.

Notice to Airmen (NOTAM)/Volcanic Ash NOTAM (ASHTAM): A NOTAM is a statement concerning the establishment, condition or change (e.g., hazard) in any component of the NAS. The ASHTAM serves as a status report for volcanoes that are active, but not necessarily erupting.

Pilot Report (PIREP): A report of meteorological phenomena encountered or observed by the flight crew while the aircraft is in flight.

Aerodrome Forecast (TAF): A forecast prepared for specific airports of important aviation parameters such as ceiling and visibility, winds and weather/obstructions to vision.

Volcanic Ash Forecast Transport and Dispersion Model (VAFTAD): A graphic depiction of the Volcanic Ash Advisory and a projection of the expected transport of the ash cloud over a specified period of time in space and flight level.

Volcanic Ash Advisory Statement (VAA): A report distributed in text form to air traffic service units and meteorological watch offices concerning the presence of a volcanic ash cloud.

User Needs as Documented in the FAA's User Needs Analysis

Capability shortfalls and goals are stated quantitatively in the UNA for each attribute. Qualitative descriptions of stated needs can be summarized as follows:

- In general, integration of the various agencies responsible for generating information on volcanic eruptions and ash clouds, to include a collaborative approach that (a) informs all stakeholders on the most current information and (b) permits all stakeholders to participate in updating information. There is no common database of text and graphic products that all users can access, which adversely affects the collaborative decision-making process. Stakeholders include airlines (dispatch, flight operations, meteorology), air traffic management and control, NWS, USGS.
- Improved detection of volcanic eruptions globally, to include forecasts of volcanic activity and characterization of the initial ash cloud.
- Better characterization of the ash cloud as the event progresses:
 - Detection accuracy, location, horizontal extent
 - Vertical extent of hazard
 - Ash density and chemistry
 - Differentiate volcanic ash hazard from meteorological cloud
- More frequent product updates.
- Improved timeliness of updates (from observation or product generation to user access).
- Better forecasts:
 - Location, horizontal extent
 - Vertical extent of hazard
 - Ash density and chemistry
 - Longer valid time
 - Dissemination for flight planning
- Better training for airline operation centers (AOCs), flight crews, and air traffic control specialists.
- Ready access to all information for all users (AOCs, flight crews, and air traffic control specialists) including graphical updates to the airborne flight crew.
- Regarding graphical products, they need to be higher resolution and referenced to planned flight profile.

Specific scientific and engineering plans and tasks have been defined by the OWPDT in response to these formal user needs. We emphasize that considerable research on defining volcanic ash hazards and detection of dangerous eruptions is already underway. The OWPDT plans to assume an integration role as these new capabilities emerge, as well as defining new research areas as satellite detection capability improves. Although the OWPDT's initial focus is on the Washington and Anchorage Volcanic Ash Advisory Centers (VAAC), coordination with the Darwin, Tokyo, and Montreal VAACs is also planned. The Team also includes NASA, the U.S. Geological Survey, the U.S. National Weather Service, and other centers of expertise in satellite sensing technologies and the characterization of volcanic ash hazards.

Plans and Progress

In its role as integrator, the OWPDT hopes to bring together the research and development that targets the volcanic ash hazard to optimize the quality of information provided to users, recognizing that no one piece of data will complete the process. Therefore, our focus will be on the use of "expert system" or fuzzy engine integration of diverse data sources and diagnostics to address the detection and dispersion problems. The OWPDT is also teaming with the NWS and NOAA's Forecast Systems Laboratory to develop a collaborative display concept and tool that will host emerging automated products and allow the stakeholders to view them and collaboratively alter them as required. These, of course, are long-range goals; however, they represent the best path to operations that will begin to address the formally documented user needs. We plan to introduce new capabilities to operations as they complete user evaluations and verification. Finally, through applied research, we intend to identify new satellite sensing capabilities that in the long term might be included in future geostationary satellites that can better detect and track volcanic ash plumes.

Some of the specific tasks the OWPDT has identified thus far include:

- Integration and display of VA SIGMET graphics and advisories on the OW web site (<http://www.rap.ucar.edu/projects/owpdt/>), representing an early capability. This display is currently running in test mode, creating global graphics from textual SIGMETs with a 97% success rate. Figure 1 shows the current OW domains and an example display.
- Ultimately, near-complete automation, with minimal mandatory human intervention.
- Capability to issue short-term pre-eruption advisories during episodes of potential volcanic unrest. Inclusion of geophysical data and input from the geosciences community.
- Improved detection of remote, unmonitored volcanic eruptions, possibly using a combination of teleseismic and satellite data.
- Incorporation of recently developed satellite interpretation technologies (e.g., multispectral analysis and channel splitting) to enhance ash cloud tracking. The OWPDT collaborates with several satellite centers of excellence with the goals of using current sensing technologies better, and identifying promising future technologies as well. For example (there are others),
 - The Moderate Resolution Imaging Spectroradiometer (MODIS) data has demonstrated considerable potential for mapping several characteristic constituents of the ash cloud, including the ash particles, on the basis of distinct radiative properties in the thermal infrared.
 - The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrumentation is ideal for detecting the thermal anomalies associated with volcanic eruptions. It has even been suggested that ASTER data may be used to identify regions of volcanic unrest, potentially allowing the forecast of an increased eruption risk. Although ASTER data has limitations that are inherently associated with the “on demand” nature of the instrument, the high spatial resolution of the data set may be extremely useful when available.
 - The Multi-angle Imaging Spectroradiometer (MISR), which heavily emphasizes aerosol measurements, may provide additional capability to detect and monitor ash clouds of sufficient age that they are no longer thermally anomalous.
- The Advanced Microwave Scanning Radiometer for EOS (AMSR-E) may prove useful for detection of young ash plumes when millimeter-sized particles may still be entrained. Data from this sensor may alleviate problems mentioned above in the detection of young ash plumes.
- Improvements to plume and ash cloud dispersion modeling, including high-resolution wind-field modeling and realistic particle size distributions. A fuzzy integration of several dispersion modeling systems, taking advantage of the strengths of each, could improve dispersion forecasts.
- Development of a global, high-resolution, satellite-derived wind field that can be integrated with the dispersion model system.
- Incorporation of “intelligent systems” capability, allowing the integration of a wide variety of input sources.
- Output will be graphical and generated in response to a user request, accessible even to airborne flight crews.
- Ash cloud characterizations will consist of detailed density contours, as opposed to the simple “visible cloud outlines” that are currently distributed.
- Task-oriented training for both meteorological and aviation user communities.

Conclusion

The OWPDT has an ambitious plan to help improve the current volcanic ash information provided to aviation end-users, and is continuing work to establish collaborations with agencies and institutions that have needed expertise. Of particular interest is the realization that current sensing technologies might not have the capabilities to satisfy needs completely, and NASA’s remote sensing work supporting the design of future satellite sensing suites will definitely be a crucial element of the OWPDT’s efforts. Meanwhile, as incremental capabilities emerge and are verified, they will be introduced to the operational community to help mitigate both the safety and efficiency impacts the volcanic ash hazard has on aviation.

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expressed are those of the author and do not necessarily represent the official policy or position of the FAA.

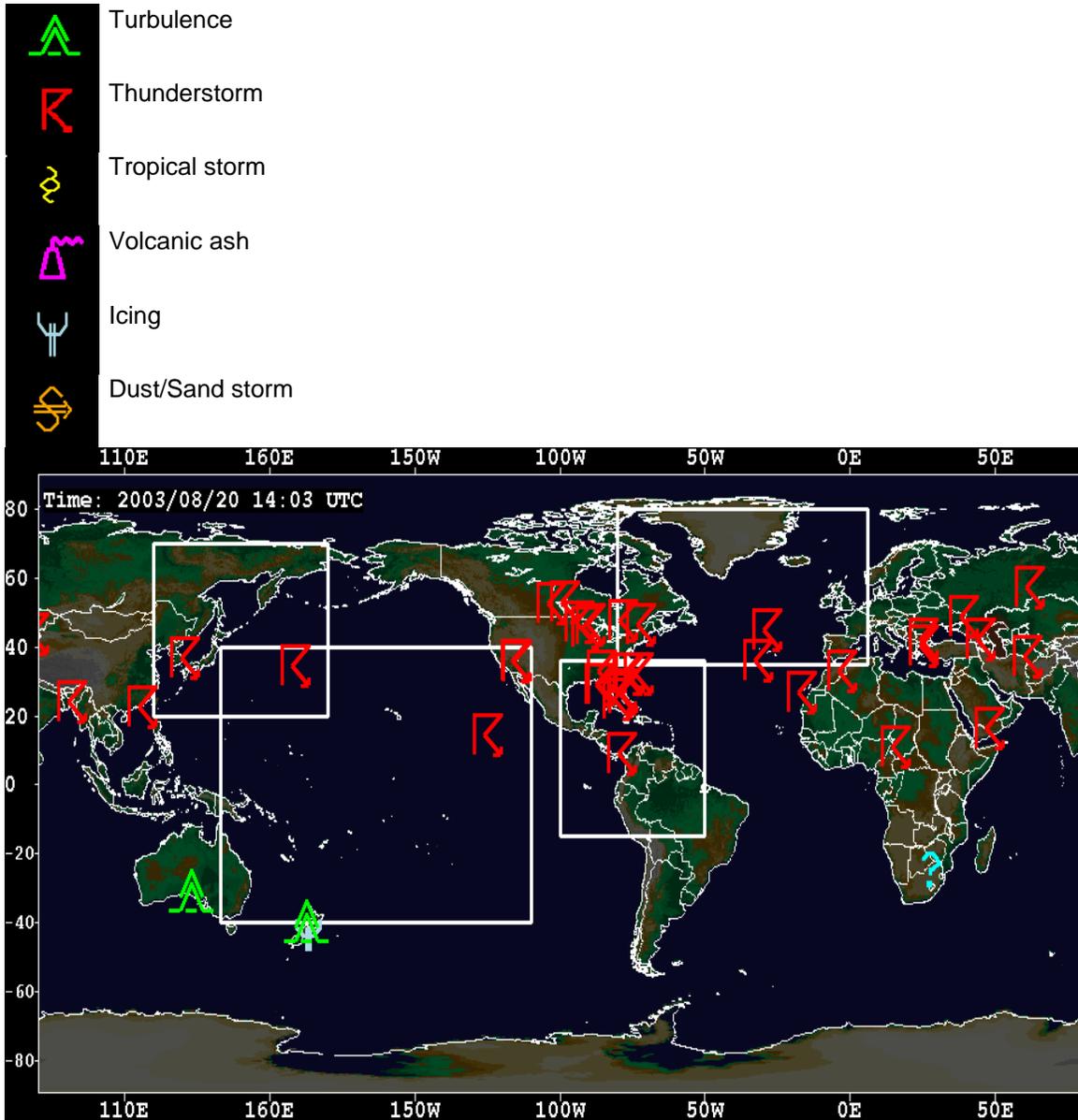


Figure 1

EXPLOSIVE VOLCANIC ERUPTIONS ACROSS THE HEAVILY TRAVELED NORTH PACIFIC AIR ROUTES: FREQUENCY, DURATION, AND IMPACT ON AVIATION

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The 100 historically active volcanoes (about 1/6 of the world's active volcanoes) that rim the North Pacific along the Alaska Peninsula, Aleutian Islands, Kamchatka Peninsula, and the Kurile Islands are part of the highly explosive "Pacific Rim of Fire". Analysis of the past 200-year record indicates that these volcanoes collectively average 3-5 eruptions/year. Most of these eruptions are relatively short-lived events lasting only a few days producing limited ash emission to low altitudes; however, a significant minority of eruptions last for months or even a few years. The 1989-90 eruption of Redoubt volcano near Anchorage, for example, lasted 4 months and had at least 20 explosive events that resulted in ejection of volcanic ash to >30,000 feet. Prevailing winds commonly carry volcanic ash across the North Pacific (NOPAC) and Russian Far East air route tracks that carry as many as 240 cargo and passenger flights per day. About 5 days/year, volcanic ash from these eruptions is at cruise altitudes of > 30,000 feet ASL and perhaps on another 10-15 days, airborne volcanic ash is at sufficient altitude to be of potential concern to aircraft routing, payloads, and scheduling. The severity of the hazard is indicated by the past 20 year record that shows encounters between airborne volcanic ash and commercial aircraft in the North Pacific have caused an estimated \$100 million dollars damage to aircraft, frequently disrupted air traffic, and occasionally required the closing of airports. This impact on aviation has led to the establishment of a color code to rapidly alert the aviation community to hazardous conditions, increased seismic and satellite monitoring, and detailed geologic studies to determine eruptive histories of active volcanoes throughout the region.

**FIRST 8 HOURS OF VOLCANIC ERUPTIONS: A NORTHWEST AIRLINES EXAMPLE &
RECOMMENDATION OF REVISED FLOW OF ASH INFORMATION FOR AVIATION**

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Currently, according to ICAO Annex 3, there are five steps in the process of notifying pilots and dispatchers of volcanic ash or volcanic eruptions. This process cuts across a spectrum of organizations and professionals. It requires close coordination to ensure that all airlines in the affected airspace receive the needed information for the safety of flight. Time is of the utmost importance in getting the message out. Even though ICAO describes the functional responsibilities for Meteorological Watch Offices, Volcanic Ash Advisory Centers, Volcano Observatories, and Area Control Centers, there is a need to re-examine the inter-relationships between these organizations and how information is gathered and exchanged. This paper will describe not only the existing protocol but provide a conceptual framework of how to streamline or improve the standardization of exchanging information and data based on prior Northwest Airlines experience and deficiencies in the system.